

Foundations of Modern Networking

SDN, NFV, QoE, IoT, and Cloud

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Chapter 13

Cloud Computing

Cloud Computing

- NIST defines cloud computing as:

A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models.

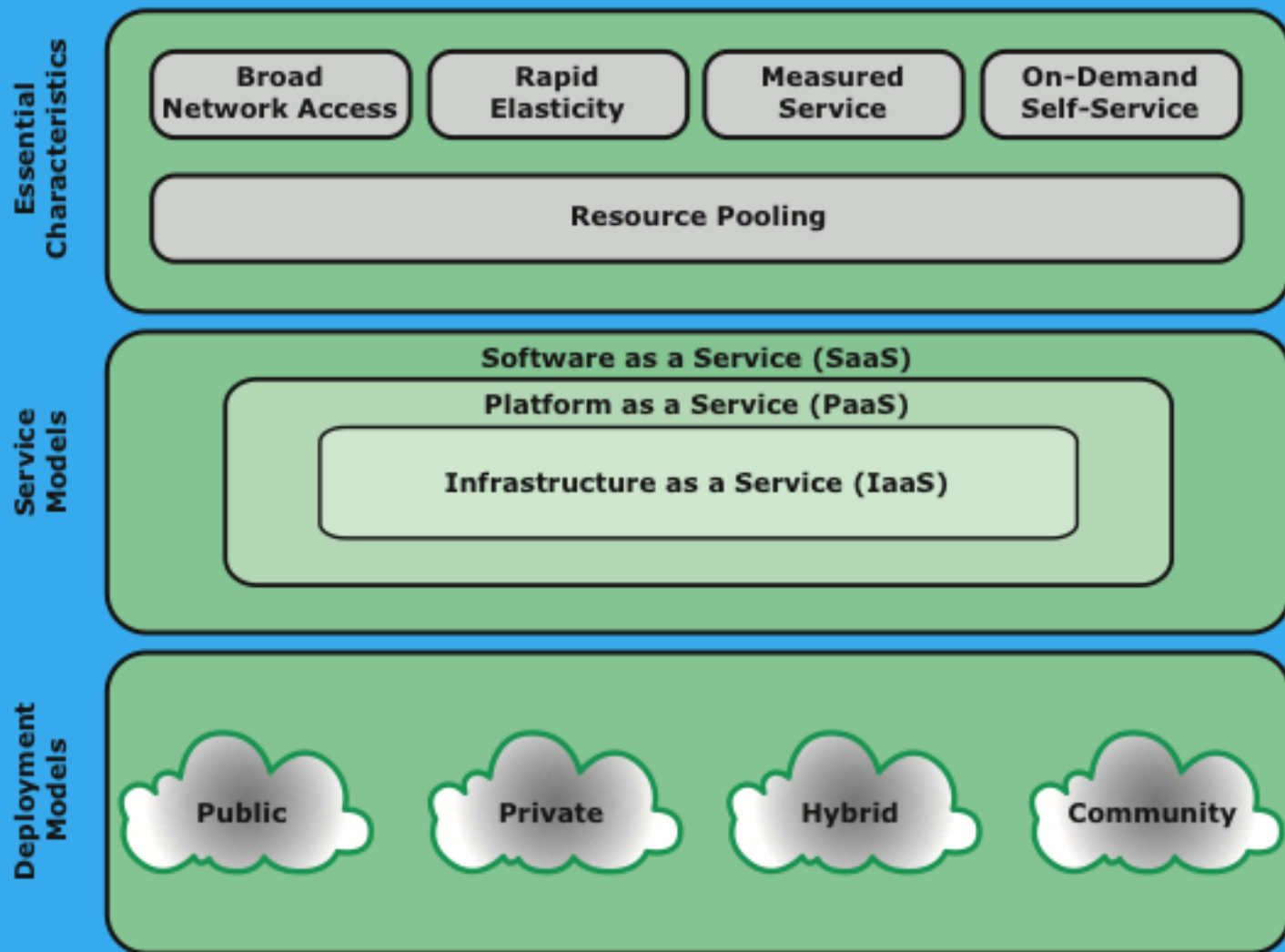


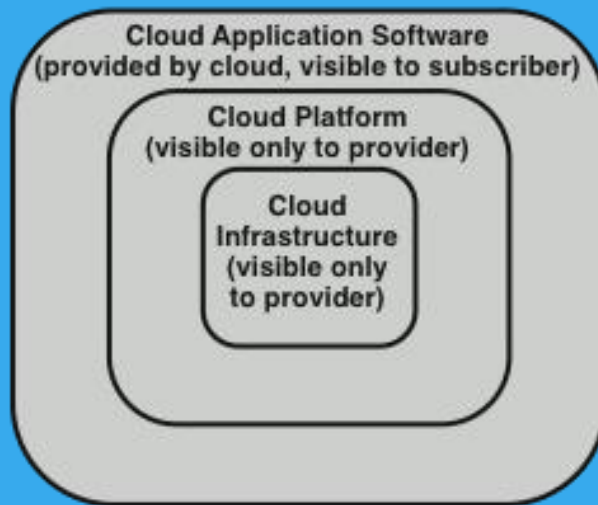
Figure 13.1 Cloud Computing Elements

Cloud Networking

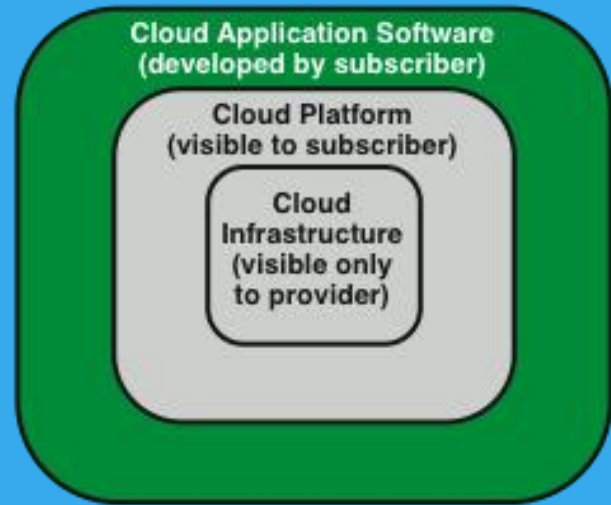
- Refers to the networks and network management functionality that must be in place to enable cloud computing
- Most cloud computing solutions rely on the Internet, but that is only a piece of the networking infrastructure
- One example of cloud networking is the provisioning of high-performance/high-reliability networking between the provider and subscriber
 - In this case, some or all of the traffic between an enterprise and the cloud bypasses the Internet and uses dedicated private network facilities owned or leased by the cloud service provider
- More generally, cloud networking refers to the collection of network capabilities required to access a cloud, including making use of specialized services over the Internet, linking enterprise data centers to a cloud, and using firewalls and other network security devices at critical points to enforce access security policies

Cloud Storage

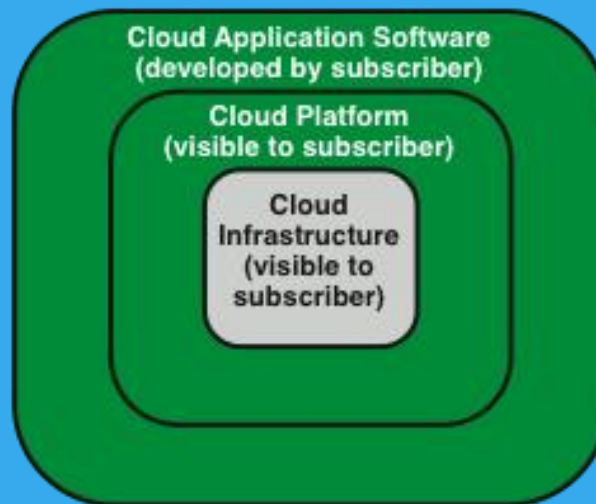
- Cloud storage can be thought of as a subset of cloud computing
- In essence, cloud storage consists of database storage and database applications hosted remotely on cloud servers
- Cloud storage enables small businesses and individual users to take advantage of data storage that scales with their needs and to take advantage of a variety of database applications without having to buy, maintain, and manage the storage assets



(a) SaaS



(b) PaaS



(c) IaaS

Figure 13.2 Cloud Service Models

Software as a Service (SaaS)

- A SaaS cloud provides service to customers in the form of software, specifically application software running on, and accessible in, the cloud
- SaaS follows the familiar model of web services, in this case applied to cloud resources
- SaaS enables the customer to use the cloud provider's applications running on the provider's cloud infrastructure
- The applications are accessible from various client devices through a simple interface such as a web browser
- Instead of obtaining desktop and server licenses for software products it uses, an enterprise obtains the same functions from the cloud service
- The use of SaaS avoids the complexity of software installation, maintenance, upgrades, and patches

Platform as a Service (PaaS)

- A PaaS cloud provides service to customers in the form of a platform on which the customer's applications can run
- A PaaS cloud provides useful software building blocks, plus a number of development tools, such as programming language tools, runtime environments, and other tools that assist in deploying new applications
- In effect, PaaS is an operating system in the cloud
- PaaS is useful for an organization that wants to develop new or tailored applications while paying for the needed computing resources only as needed and only for as long as needed

Infrastructure as a Service (IaaS)

- With IaaS, the customer has access to the resources of the underlying cloud infrastructure
- IaaS provides virtual machines and other abstracted hardware and operating systems
- IaaS offers the customer processing, storage, networks, and other fundamental computing resources so that the customer can deploy and run arbitrary software, which can include operating systems and applications
- IaaS enables customers to combine basic computing services, such as number crunching and data storage, to build highly adaptable computer systems

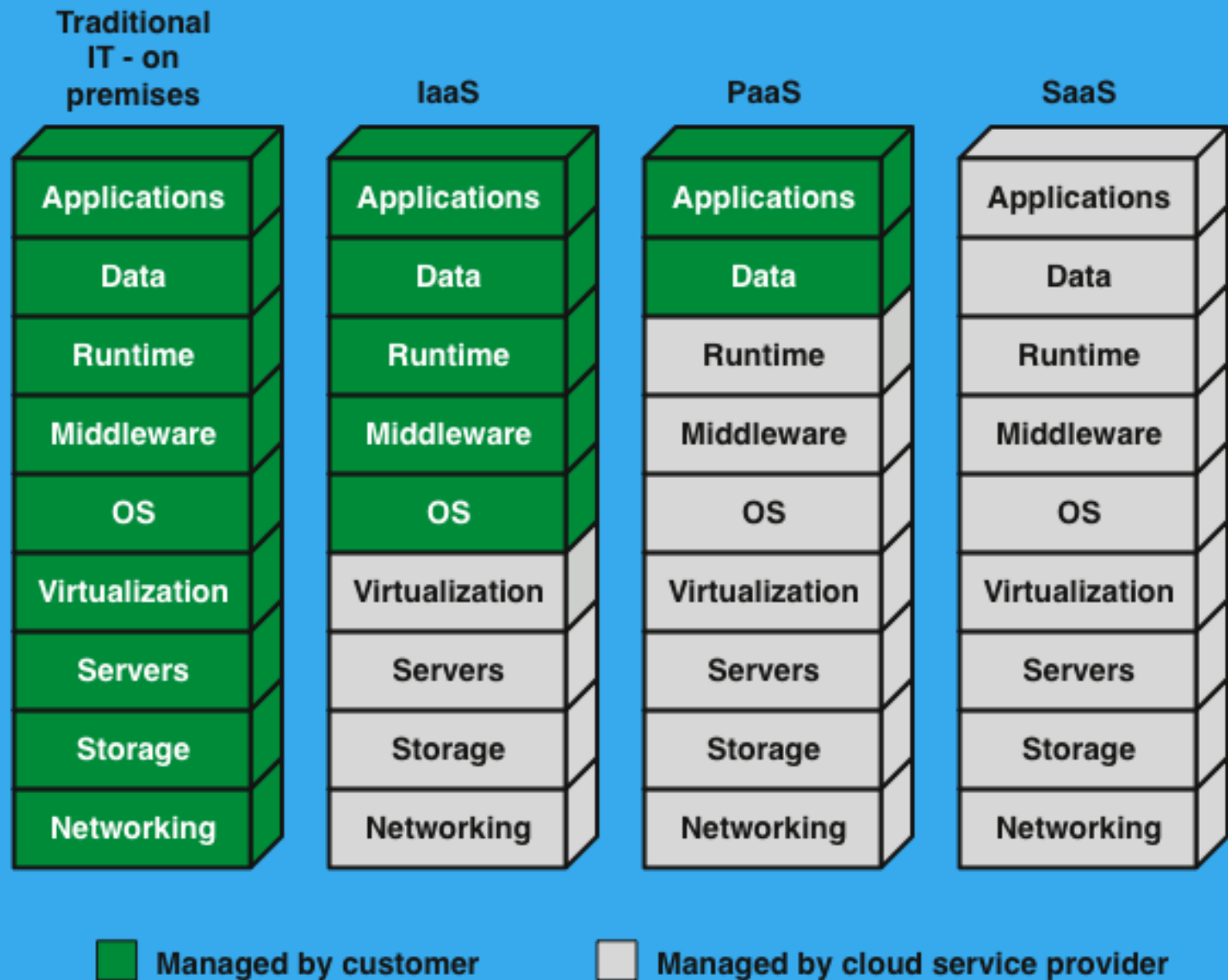


Figure 13.3 Separation of Responsibilities in Cloud Operation

Other Cloud Services

Communications as a Service (CaaS)

- The integration of real-time interaction and collaboration services to optimize business processes
- This service provides a unified interface and consistent user experience across multiple devices

Compute as a Service (CompaaS)

- The provision and use of processing resources needed to deploy and run software
- CompaaS may be thought of as a simplified IaaS with the focus on providing computer capacity

Data Storage as a Service (DSaaS)

- The provision and use of data storage and related capabilities
- DSaaS describes a storage model where the client leases storage space from a third-party provider
- Data is transferred from the client to the service provider via the Internet, and the client then accesses the stored data using software provided by the storage provider
- The software is used to perform common tasks related to storage, such as data backups and data transfers

Network as a Service (NaaS)

- NaaS involves the optimization of resource allocations by considering network and computing resources as a unified whole
- NaaS can include flexible and extended virtual private network, bandwidth on demand, customer tunneling, multicast protocols, security firewall, intrusion detection and prevention, wide-area network, content monitoring and filtering, and antivirus

XaaS

- XaaS is the latest development in the provisioning of cloud services
- XaaS is becoming increasingly attractive to customers because it offers these benefits:
 - Total costs are controlled and lowered
 - Risks are lowered
 - Innovation is accelerated
- The acronym has three generally accepted interpretations:

Anything as a Service

- Where *anything* refers to any service other than the three traditional services

Everything as a Service

- This version is meant to suggest that the cloud service provider is providing a wide range of service offerings

X as a Service

- Where X can represent any possible cloud service option

Public Cloud

- A public cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services
- The cloud provider is responsible both for the cloud infrastructure and for the control of data and operations within the cloud
- A public cloud may be owned, managed, and operated by a business, academic, or government organization, or some combination of them

Public Cloud

- In a public cloud model, all major components are outside the enterprise firewall, located in a multitenant infrastructure
- Applications and storage are made available over the Internet via secured IP and can be free or offered at a pay-per-usage fee
- This type of cloud supplies easy-to-use consumer-type services (Yahoo! Mail, Facebook, Google on-demand, etc)
- Public clouds typically provide no or lower service level agreements and may not offer the guarantees against data loss or corruption found with private or hybrid cloud offerings
- The major advantage of the public cloud is cost; the principal concern is security

Private Cloud

- A private cloud is implemented within the internal IT environment of the organization
- The organization may choose to manage the cloud in house or contract the management function to a third party
- In addition, the cloud servers and storage devices may exist on premises or off premises
- Private clouds can deliver IaaS internally to employees or business units through an intranet or the Internet via a virtual private network, as well as software or storage as services to its branch offices
- A key motivation for opting for a private cloud is security; other benefits include easy resource sharing and rapid deployment to organizational entities

Community Cloud

- A community cloud shares characteristics of private and public clouds
 - Like a public cloud, the cloud resources are shared among a number of independent organizations
 - Like a private cloud, a community cloud has restricted access
- The organizations that share the community cloud have similar requirements and, typically, a need to exchange data with each other
- One example of an industry that is using the community cloud concept is the healthcare industry
- A community cloud can be implemented to comply with government privacy and other regulations
- The cloud infrastructure may be managed by the participating organizations or a third party and may exist on premises or off premises

Hybrid Cloud

- The hybrid cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability
- With a hybrid cloud solution, sensitive information can be placed in a private area of the cloud, and less sensitive data can take advantage of the benefits of the public cloud
- A hybrid public/private cloud solution can be particularly attractive for smaller businesses
- Many applications for which security concerns are less can be offloaded at considerable cost savings without committing the organization to moving more sensitive data and applications to the public cloud

Table 13.2 Comparison of Cloud Deployment Models

	Private	Community	Public	Hybrid
Scalability	Limited	Limited	Very high	Very high
Security	Most secure option	Very secure	Moderately secure	Very secure
Performance	Very good	Very good	Low to medium	Good
Reliability	Very high	Very high	Medium	Medium to high
Cost	High	Medium	Low	Medium

NIST Cloud Computing Reference Architecture

- NIST SP 500-292, *NIST Cloud Computing Reference Architecture*, September 2011, establishes a reference architecture, described as:

The NIST cloud computing reference architecture focuses on the requirements of “what” cloud services provide, not a “how to” design solution and implementation. The reference architecture is intended to facilitate the understanding of the operational intricacies in cloud computing. It does not represent the system architecture of a specific cloud computing system; instead it is a tool for describing, discussing, and developing a system-specific architecture using a common framework of reference.

ITU-T Cloud Computing Reference Architecture

- The ITU-T cloud computing architecture defines three actors:

Cloud service customer or user

A party that is in a business relationship for the purpose of using cloud services

Cloud service provider

A party that makes cloud services available

Cloud service partner

A party which is engaged in support of, or auxiliary to, activities of either the cloud service provider or the cloud service customer, or both